STABILITY OF ALIGNMENT DURING EXTENDED HOLD TIMES IN THE AIMING PHASE OF ELITE ARCHERS

Lewis Marsden

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No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.

Signed ....

Date ....

Stability of Alignment During Extended Hold Times in the Aiming Phase of Elite Archers

The purpose of this study was to investigate the differences in the stability of alignment in elite archers when hold times in the aiming phase are increased. Eight elite archers (age = 21 ± 2.3 year, height = 1.79 ± .13m, mass = 78.35 ± 7.27kg) took part in the study (two females and six males). Participants shot six arrows under three separate conditions: 100%, 200% and 300% of average hold times in the aiming phase. The velocities of the key anatomical landmarks of alignment (LRSP, LLHE, LAP, RAP, RMHE, RRSP) were measured under all conditions and arrow score was recorded as a measure of performance. One-way repeated measures analysis of variance (ANOVA) and bonferroni post-hoc statistical analysis were adopted for kinematic variables. Friedman's test of differences betweem repeated measures and Wilcoxen signed-rank test were adopted for arrow score. It was found that velocities at five of the six kinematic variables increased significantly as HT increased (LRSP: $p < .001$, LLHE: $p = .022$, LAP: $p <.001$, RMHE: $p = .001$, RRSP: $p < .001$). Arrow scores decreased significantly as HT increased ($p = .02$). It was concluded that increasing HTs during the aiming phase decreases the stability of alignment and subsequently reduces arrow score.

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Introduction

Archery is a static sport that requires strength, endurance and stability of the upper body, the trunk and the arms. Success is defined as the ability to shoot an arrow at a target within a given timespan with accuracy. Nishizono, Shibayama, Izuta and Saito (2008) describes a six phase sequence of movements an archer must perform in order to produce repeatable release and consistent scoring: bow holding, drawing, full draw, aiming, release and follow through. The aiming and release phase must be well balanced and highly reproducible to achieve commendable results in a competition (Mohammand & Azhar, 2007).

In the coaching literature, understanding and achieving proper alignment in archery is deemed to be imperative to consistent scoring (Archery Australia, 2007). Alignment is typically observed in the coronal plane and is present through the orientation of the arms and shoulder girdle in the aiming phase. Despite application by elite coaches, the role and maintenance of alignment is yet to be recognized in scientific journals with regards to the impact it could have on scoring performance. Good alignment aids execution, minimising the detrimental effects poor execution may have on scoring (Archery GB, 2012). Proper alignment ensures the archer adopts a technique that minimises the muscular demand whilst resisting the compressive forces of the bow, through the correct orientation of the bones. Coaches commonly describe the feeling of achieving proper alignment as being inside the bow as opposed to holding it from the outside, offering greater stability when in the full draw position by reducing the reliance on muscular control. Whilst proper alignment prioritizes a technique that minimizes muscular demand, muscles play an important role maintaining the correct posture and releasing the arrow. Controlling the compressive forces created whilst drawing a bow using the joints will reduce the reliance of muscular control and is thought to improve stability.

Amongst a limited amount of published research with respect to biomechanics in archery, postural stability is a popular focus (Mohammad & Azhar, 2007; Stambolieva, Otzetov, Petrova, Ikonomov, & Gatev, 2015). Ertan (2009) states that the performance variables of muscular strength, endurance and stability are required specifically in the trunk, shoulder girdle and the arms to warrant shooting accuracy in archery. An archer's skill level is determined by their ability to shoot an arrow at the center of a specific target within a given timeframe. In order to complete this task, athletes must reduce unnecessary movements that can inhibit stability, subsequently reducing the chance of shooting accurately (Lin, & Hwang, 2005; Kuo, Chi, Yu, & Tsung, 2005). In precision aiming tasks, postural stability has been commonly highlighted as an important variable in determining the success of the task (Ball, Best & Wrigley, 2003; Stambolieva et al., 2015). Mohammad & Azhar (2007) established a significant relationship between postural sway and scoring performance in skilled population of archers, finding smaller deviations in the center of pressure (CoP) during the aiming phase led to increased arrow scores. Coaches identify the most important phase in determining the success of a shot in archery is the aiming and release phase. An archer draws the bow and aims at the target, they must maintain the posture of the trunk and the arms to ensure that arrow remains aligned with the center of the target. Balasubramaniam, Riley, & Turvey (2000) suggests that when postural movements in the aiming phase are minimized as the archer can focus on the target, improving scoring consistency.

Stability of the arms and trunk must be maintained in order to obtain a small deviation in score. A precision aiming task is defined as a static sport that demands strength and endurance of the shoulder girdle (Soylu, Ertan, & Korkusuz, 2006). In archery, once the archer is focused on aiming the site of the bow at the target face, the shoulder muscles preserve the alignment of the arrow with the target whilst at full draw. Whilst maintaining alignment during the aiming-phase, fluctuations in the orientation of limb position can be recorded throughout shoulder contractions. These fluctuations that are prevalent whilst completing maintained voluntary postural tasks are known as 'physiological tremor' (Halliday, Conway, Farner & Rosenberg, 1999). The tremor that occurs during the conservation of shoulder position is a result of neuromuscular system activity for adjusting the arm posture. Therefore, Lin, Hung, Yang, Chen, Chou and Lu (2010) focused on shoulder muscle activation patterns and the challenges of muscle endurance and precision aiming. The study states that the frequency of the physiological tremor reflects the amplitude of the muscle contraction, suggesting that an increased muscular demand may degrade the precision of the task. Despite a comprehensive kinetic analysis of muscle function, the study failed to quantify any resulting kinematic alterations to technique from an increased muscular demand.

FITA (2013) coaching manual for recurve archery technique identifies that extended hold times (HTs) in the aiming phase can be prevalent during competition shooting. Extended HTs can be caused due to internal or external factors that serve to inhibit performance (i.e. windy conditions, pressure), potentially subjecting the muscles to acute fatigue. Fatigue in the mechanical performance may result in changes of motor strategy or technique. Although these changes may only be subtle, they could result in an undesirable outcome impacting arrow scores. To date there are very few studies that focus on fatigue in archery, one of which incorporated extended aiming phases into their methodology. Squadrone, Rodano and Gallozzi (1994) investigated the effect of fatigue upon archer's muscle activation strategies and technique. Despite finding no significant decrease in performance scores, increased lateral sway of the bow by as much as 39% was evident after the fatigue protocol in less skilled archers. The fatigue protocol adopted in this study consisted of each participant (n = 12) completing six sets of ten repetitions of 20-second holds in the aiming phase followed by 10 arrows with a self-selected aiming phase which were used to collect EMG, kinetic and kinematic data simultaneously. One weakness of the fatigue protocol adopted in this study is that it does not account for an individual's natural muscular capacity whilst in the aiming phase. Consider that an archer has average aiming phase of ten seconds, it could be presumed that this athlete would have an increased resistance to the onset of local fatigue in comparison to an archer with an average aiming phase of two seconds. A second weakness is the length of the aiming phase adopted for the fatigue protocol. The maximum length of time an archer is allocated to shoot a single arrows is 20 seconds, including loading the arrow, drawing the bow, aiming and releasing. As such, the muscular demand for a single repetition would far outweigh that of a single arrow shot in competition. Despite the methodological flaws in the study, it highlighted the demand to train the muscle groups critical for endurance, whilst placing emphasis on the development of a more convenient motor strategy that creates quasi-static equilibrium using the skeletal system rather than the muscular system. Pryimakov, Eider and Omelchuk (2015) found that under fatigued conditions athletes that were less adapted to physical loads may be susceptible to an increase of amplitude and synchronism of the tremors of the various body links that control upright posture, reducing the ability to dampen the vibrations and maintain alignment of the shoulder girdle ultimately decreasing shooting quality and scoring.

Consider that an archer exhibits strong reliable execution through the preservation of the alignment of the shoulder girdle and arms, but the stability of alignment deteriorates when the aiming phase extends as a result of acute fatigue. Stability in overhead alignment is of vital importance to shooting consistently and accurately during competition. Should technique deteriorate with fatigue, unstable alignment may inherently decrease scoring performance. As such, it is the aim of the study to investigate the difference in velocities of anatomical landmarks integral to alignment and scoring performance as the aiming phase is increased.

Hypothesis

Null Hypothesis 1: There will be no statistically significant difference between the velocities of the critical anatomical landmarks in overhead alignment under three separate conditions: 100, 200 and 300% average hold time in aiming phase.

Alternative Hypothesis 2: There will be a statistically significant difference between the velocities of the critical anatomical landmarks in overhead alignment under three separate conditions: 100, 200 and 300% average hold time in the aiming phase.

Null Hypothesis 2: There will be no statistically significant difference between arrow scores under three separate conditions: 100, 200 and 300% average hold time in the aiming phase.

Alternative Hypothesis 2: There will be a statistically significant difference between arrow scores under three separate conditions: 100, 200 and 300% average hold time in the aiming phase.

Methodology

Subjects

Eight elite archers (6 males, 2 females) were recruited for the study (age = 21 ± 2.3 year, height = 1.79 ± .13m, mass = 78.35 ± 7.27kg). Participants were recruited freely and willingly from the Great Britain archery programme. Subjects shot recurve bows and were free from injury 6-months prior to participation. All subjects provided consent for participation in the study, were made aware participation was voluntary and that they had the right to withdraw from the study at any time. Informed consent was obtained in writing prior to participation in the study at the ArcheryGB performance centre, Lilleshall. Dr Stephen Fallows of the University of Chester Research Ethics Committee approved the testing procedures and training programme research project on the 26th June 2015.

Design

The study was experimental and employed a repeated measures design. The dependent variables for the study include the velocities of; the left and right radial styloid process, left and right acromion process, the draw lateral humeral epicondyle, the bow medial humeral epicondyle and arrow score. The independent variable was the length of hold-time during the aiming phase (3 conditions); 100%, 200%, 300% of average hold-times.

Procedures

Participants familiarised themselves with the design of the study by completing a 5 minute archery specific warm-up (See Appendix 1), after being fitted with 5mm light reflective markers. Markers were attached to the left and right acromion process (shoulders), right humeral lateral epicondyle and left humeral medial epicondyle (elbows) and the left and right radial styloid process (wrists) using a double-sided adhesive tape (See Figure 2).

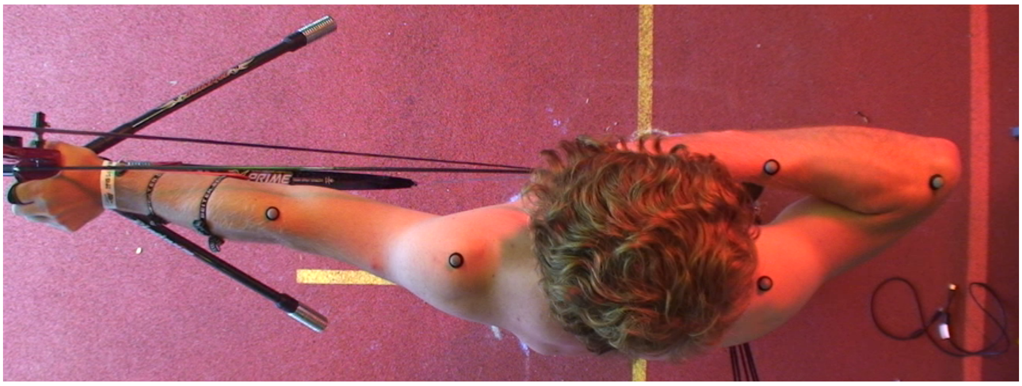

Figure 1. Sample Marker Placement for Alignment in the Coronal Plane.

Given the limited literature investing the effect of acute fatigue on kinematics pivotal to archery technique, the testing protocol was unique in nature. The protocol was sport specific, reflecting the physiological and mechanical demands of shooting arrows at various hold-times. Each participant shot 6 arrows at a 70m target to familiarise themselves with the surrounding and sight-in on the target. The first 6 arrows were self-paced with self-selected rest periods whilst being recorded with a Sony HDV video camera in the sagittal plane. The sagittal recordings were used to calculate a mean hold-time for each participant and this equated to a 100% HT (HT1) for each participant. Participants then shot another 6 arrows adopting their mean hold-time at the same target. Audible cues were used to make participants aware of when they were required to execute the shot at second intervals (hold-times were classified from the string touching the face to releasing the string). A further 6 arrows were then shot adopting a hold-time at 200% (HT 2) of their mean functional hold-time; again audible cues were given to the participants to notify when the arrow must be released. Followed by 6 arrows shot at 300% (HT3) of their mean functional hold-time using the same procedure. Finally, participants completed a single maximal hold whilst aiming the bow at the 70m-target but not shooting the arrow. Rest periods were set at a 1:1 work to rest ratio for each end of 6 arrows with a 3-minute interval between each end and each arrow was scored based on its proximity to the centre of the target using traditional scoring methods.

Kinematic data was collected using a Quintic GigE Live High-Speed camera sampling at 150fps in the coronal plane. The field of view was calibrated using a 1x1m frame and was calibrated using both vertical and horizontal points of reference. The first 6 arrows were filmed in the sagittal plane using a Panasonic HC-W850 video camera (Japan) sampling at 50Hz to establish mean hold-times. Arrow scores were input to a plotting application that allowed for the scores for each end to be exported to Microsoft Excel (2013)

Data Processing

Kinematic data was processed using Quintic Biomechanics V26. Video files were calibrated using the calibration video file and then cropped to 1 second prior to, and .3 seconds following release of the string (200 frames). Using the automatic digitisation function, each marker was located and tracked throughout the video file. The raw data was then smoothed to remove any errors that may have occurred during the digitisation process e.g. marker/skin error. The data was passed through a Butterworth low-pass filter by which Quintic offers optimal cut-off frequencies for both X and Y coordinates for each marker using residual analysis (cut-off frequencies ranged from 25-35 based on the amount movement of the markers after execution). The data was then exported to Microsoft Excel (2013). Arrow scores were collected using a bespoke arrow plotting application created for tablet, before being exported to Microsoft Excel (2013).

Statistical analyses for all kinematic measures used a repeated-measures analysis of variance (RM-ANOVA) to test overall differences between hold-time conditions for each variable. The Greenhouse-Geisser adjustment for violations of sphericity was utilised, and degrees of freedom reported were Greenhouse-Geisser adjusted based on the value of the epsilon. In addition, post-hoc comparisons were made using the bonferroni correction, resulting in a conservative estimate of significant mean differences between conditions (Vincent & Weir, 2012). Friedman's non-parametric test of differences amongst repeated measures was used to test overall differences of arrow score between hold-time conditions. Wilcoxon signed-rank test with a bonferroni correction was conducted to assess where mean population ranks differed. PASW statistics editor 22.0 (SPSS Inc., USA) was used to perform all statistical analysis.

Results

Table 1. Means and Standard Deviations for Kinematic and Performance Variables.

	Hold Time			Comparison		
Velocity (cm/s)	100%	200%	300%	A	B	C
LRSP	3.21 ± .75	3.58 ± .81	3.87 ± .86	*		*
LLHE	3.57 ± .80	3.77 ± .61	3.97 ± .71			*
LAP	3.20 ± .63	3.62 ± .73	3.80 ± .94	*		*
RAP	3.66 ± 1.12	4.07 ± 1.07	3.84 ± 1.09			
RMHE	4.14 ± 1.11	4.32 ± 1.08	4.83 ± 1.14		*	*
RRSP	3.51 ± .74	4.15 ± 1.03	4.60 ± 1.53	*	*	*
Arrow Score						
	8.6 ± .94	8.13 ± 1.18	7.75 ± 1.59			*

Note: Statistically significant comparisons using a Bonferroni correction are indicated by * ($p < .05$), comparisons are: A, 100% vs. 200%; B, 200% vs. 300%; C, 100%vs. 300%.

Table 1 shows means and standard deviations of kinematic and performance variables. All kinematic variables satisfied the assumptions of normal distribution (See Appendix 2). Mauchly's test indicated that the assumption of sphericity had not been violated, $\chi^2(2) = .416$, $p = .416$ for the LRSP. A one-way repeated measures ANOVA demonstrated a significant difference in the velocities of the LSRP between HTs, $F(2, 94) = 10.97$, p <

.001. Post-hoc comparisons using the bonferroni correction revealed a significant increase in the velocities between HT1 (m = 3.21, SD = .75) and HT2 (m = 3.58, SD = .81)(p = .035). A significant increase in velocities was also found between HT1 and HT3 (m = 3.87, SD = .86) ($p < .001$). There was no significant difference between HT2 and HT3 (p = .165).

Mauchly's test indicated that the assumption of sphericity had not been violated [$\chi^2(2) = 1.87$, $p = .393$] for the LLHE. A one-way repeated measures ANOVA demonstrated a significant difference in the velocities of the LLHE between HTs, $F(2, 94) = 3.959$, $p = .022$. Post-hoc comparison using the bonferroni correction revealed a significant increase in the velocities between HT1 (m = 3.57, SD = .80) and HT3 (m = 3.97, SD = .71) (p = .038). There was no significant difference between HT2 (m = 3.77, SD = .61) and HT3 (p = .417) or between HT1 and HT2 (p = .462).

Mauchly's test indicated that the assumption of sphericity had not been violated [$\chi^2(2) = .67$, $p = .714$] for the LAP. A one-way repeated measures ANOVA demonstrated a significant difference in the velocities of the LAP between HTs, $F(2, 94) = 14.38$, $p < .001$. Post-hoc comparison using the bonferroni correction revealed a significant increase in the velocities between HT1 (m = 3.20, SD = .63) and HT2 (m = 3.62, SD = .73)(p = .001). A significant increase in velocities was also found between HT1 and HT3 (m = 3.80, SD = .94) ($p < .0005$). There was no significant difference between HT2 and HT3 (p = .40).

Mauchly's test indicated that the assumption of sphericity had not been violated [$\chi^2(2) = .15$, $p = .928$] for the RAP. A one-way repeated measures

ANOVA demonstrated no significant difference in the velocities of the RAP between HTs, $F(2, 94) = 2.85$, $p < .063$.

Mauchly's test indicated that the assumption of sphericity had not been violated [$\chi^2(2) = 2.35$, $p = .309$] for the RMHE. A one-way repeated measures ANOVA demonstrated a significant difference in the velocities of the RMHE between HTs, $F(2, 94) = 7.35$, $p = .001$. Post-hoc comparison using the bonferroni correction revealed a significant increase in the velocities between HT1 (m = 4.14, SD = 1.11) and HT3 (m = 4.83, SD = 1.14)($p = .003$). A significant increase in velocities was also found between HT2 (m = 4.32, SD = 1.08) and HT3 ($p < .009$). There was no significant difference between HT1 and HT2 ($p = 1.00$).

Mauchly's test indicated that the assumption of sphericity had been violated [$\chi^2(2) = 7.59$, $p = .022$] for the RRSP. A one-way repeated measures ANOVA demonstrated a significant difference in the velocities of the RRSP between HTs, $F(1.74, 81.59) = 18.74$, $p < .001$ (Greenhouse-Geisser). Post-hoc comparison using the bonferroni correction revealed a significant increase in the velocities from HT1 (m = 3.52, SD = .74) to HT2 (m = 4.15, SD = 1.02)($p < .0005$). A significant increase in velocities was also found between HT1 and HT3 (m = 4.60, SD = 1.53) ($p < .0005$); and between HT2 and HT3 ($p = .047$).

A non-parametric Friedman test of differences among repeated measures was conducted to compare the mean scores across the separate conditions: HT1(m = 8.60, SD = .94), HT2(m = 8.13, SD = 1.17) and HT3(m = 7.75, SD = 1.59). The Friedman test rendered a significant difference in the mean target scores; $\chi^2 = 7.80$, $p = .02$. Post-hoc analysis with Wilcoxon signed-rank test was conducted with a bonferroni correction manually applied, resulting in a significance level set at $p < .017$. A significant decrease in target scores was found between HT1 and HT3 ($Z = -2.91$, $p = .004$), whilst there was no significant difference between HT1 and HT2 ($Z = -2.05$, $p = .04$) or HT2 and HT3 ($Z = -1.41$, $p = .16$.

Discussion

The present study predicted that extending the aiming phase whilst shooting an arrow would decrease the stability of alignment prior to execution and inhibit scoring performance. With the exception of the RAP ($\chi^2(2) = 2.35$, $p = .309$), all anatomical landmarks critical to the maintenance of alignment showed significant increases in velocities between HT1 and HT3. Similarly, arrow scores decreased significantly ($\chi^2 = 7.80$, $p = .02$) between HT1 and HT3 ($Z = -2.91$, $p = .004$) as the aiming phase extended. As such, we reject null hypothesis 1 and 2 and accept the alternative hypotheses.

Key Findings

As hypothesised, the velocities of anatomical landmarks that form alignment in the coronal plane increased significantly as the aiming phases were extended. Significant increases in velocities were observed at: LRSP, LLHE, LAP, RMHE, and RRSP between HT1 and HT3. The RRSP displayed the greatest increase in mean velocities amongst all the kinematic variables. Noticeably, it also had the greatest standard deviation during HT3 suggesting increased variability in the stability of the draw wrist. This may be explained by the markers proximity to the draw hand, the increased velocity could be a result of the participant’s inability to resist the compressive forces of the bow. The RAP was the only variable that displayed no statistically significant differences in mean velocities as hold-time increased. The immediacy of the RAP to the proximal end of the segment may offer an explanation as to why no differences were found. In contrast to the kinematic variables, HT's increased and the stability of the arms and shoulder girdle decreased, a significant decrease in arrow score was observed. Interestingly, as HT increased the standard deviation of mean arrow scores followed suit displaying an increased variability in scoring performance. A statistically significant difference in arrow scores was only prevalent between HT1 and HT3 ($p < .004$), suggesting that significant increases in the velocities of the LRSP, LAP and RRSP evident between HT1 and HT2 were not detrimental to the performance outcome. However, beyond statistical significance arrow scores still decreases between HT1 ($m = 8.6$, $SD = .94$) and HT2 ($m = 8.13$, $SD = 1.18$) and there is also an increase in the variability of scoring evident when observing the standard deviations.

This is the first study to investigate the stability of alignment in recurve archery, as such it difficult to make direct comparisons with the limited literature surrounding archery. However, these results supplement the findings of Squadrone and Rodano (1994) who reported correlations of mean duration of the aiming phase and bow lateral sway with FITA scores of $r = -.72$ and $r = -.67$ respectively. Similarly, they support Squadrone, Rodano and Gallozzi (1994) which reported an increase in lateral bow sway following a fatigue protocol incorporating repeated bouts of extended aiming phases. Kuo et al. (2005) states that increased aiming stability ensures uninterrupted flight trajectory of an arrow and gives impact to the performance outcome of the shot, a statement that is supported by the findings of the present study.

Mohammad and Azhar (2007), using multiple regression analysis discovered a significant relationship between an increase in postural sway and subsequent decrease in arrow score. Although this study measured CoP as a means of postural stability, it would appear that the kinematic variables chosen to assess stability of the arms and shoulder girdle in the present study display a similar trend. Interestingly, the same study reports that postural instability during the aiming phase is insignificant to shooting performance ($p = .367$) and that the release phase is the most important phase when considering scoring performance ($p = .001$), which contradicts the findings of the current study. This could be explained by the difference in variables chosen to assess stability (i.e. kinetic vs. kinematics), alternatively there could be discrepancies in the definitions of each phase as the study fails to outline where one phase ends and another begins.

These findings of the current also serve to support the notion of Lin et al. (2010) when investigating muscle activation patterns in the shoulders during precision tasks. The study reports that the frequency of a physiological tremor is equivalent to the amplitude of the muscle contraction, leading to degraded precision of a task that requires an increased muscular demand. Primakov, Eider and Omelchuk (2015) offers similar results when studying pistol shooting. The study found that holding a pistol in an outstretched arm for a prolonged period of time decreases postural stability of the arms and shoulder girdle, with increased physiological tremor as the athlete began to fatigue. Correlational analysis demonstrated that whilst holding the pistol-outstretched interaction of the functional systems of posture stability control increase. It would appear that in the present study, as the hold-time increases so does the muscular demand which is subsequently met with a decrease in stability observed through increased velocities across the arms and shoulder girdle. Although the significant differences in mean velocities of the anatomical landmarks are relatively small, they must not be underestimated as can be seen with the subsequent arrows scores recorded. Given that an archer is shooting at a target 70m away from the shooting line, errors in technique are amplified as the distance the arrow travels increases.

Limitations

The current study is not without limitations. Given the standard of archers used for the study, sample size was restricted by the number of athletes currently on the ArcheryGB programme. Due to precautionary measures taken by the sports science and medicine team that provides support for GB athletes, a number of athletes were removed from the sample as to not aggravate pre-existing injuries and this reduced the sample size further. A second limitation was the availability and accessibility of suitable equipment for recording and collecting scientific data. Ideally, the study would have incorporated kinetic analysis in order to make comparisons with previous literature and inform future practice but this equipment was not available. Participants used their own equipment in the study to help replicate performance in competition, however bows vary in weight and this may be influenced the rate at which instability manifests. Similarly, the draw weight an athletes selects could influence stability in alignment with longer aiming phases being harder to complete with a heavy poundage.

Practical Implications

Stability in archery has been identified as an important indicator of performance in archery. It not only refers the postural stability of the body as whole, but also the stability and orientation of each segment; including the arms and shoulder girdle. The findings of this study offer insight to athletes, coaches and sports science practitioners alike. Increasing the length of the aiming phase has highlighted a decrease of stability in alignment and has had a negative impact on scoring performance. It highlights a demand for specific training programs to improve the isometric capacity of the muscles in their resistance to acute fatigue. Practitioners may benefit from increasing the isometric workload of strength and conditioning programmes in order to increase the resistance to the instability. Alternatively, coach and athlete could implement strategic changes to ensure the aiming phase does not extend beyond average functional HTs, executing the release of the shot earlier.

Further Research

This study highlights instability in alignment when HTs during the aiming-phase increase in recurve archery. Further research is needed to ascertain methods of improving stability in alignment through the introduction of specific bow-training drills and modifications to strength and conditioning programmes. Additional methodologies to assess a wider range of kinematic and kinetic variables would provide a stronger understanding of the contributing factors to decreased scoring performance during extended HTs.

Conclusions

In summary, the present study serves to highlight the detrimental effect that extended HTs during the aiming phase can have on the preservation of technique and performance in recurve archery. The analysis of anatomical landmarks offered insight into the movement characteristics of the arms and the shoulder girdle when faced with an increased muscular demand. Given this information, it is reasonable to assume that extended HTs in the aiming phase result in instability in the alignment of recurve archers.

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Appendices

Appendix 1 – Pre-shoot warm up

Pre-shoot archery warm up

Section	Drill	Reps	Guidelines
Dynamic mobilisation	Fwd - backward arm swings	14	The purpose of this section is to raise core body temperature and loosen joints. Begin slow and controlled
	Alternate OH swings with trunk rotation	8 e/w	
	Crucifix hand reaches	10	
	Full lateral raises	6	
Activation	Crucifix internal external rotation	6	During this section the aim is to activate, or fire up key muscle groups, namely the cuff and traps
	Alternate arm abducted position internal external rotation	12	
	Scaption position internal external rotation	6	
	4 point scap protract retracts	2 each	
	Alternate scap depression	12	
Mobilisation	Behind back, across body, retraction sequence	6 e/a	Mobilisation should ensure that your flexibility around joints is consistant practise day to practise day, which should help consistency of feel
	Multi plane head movement sequence	2x through	
	Lateral neck stretch	2 e/w	
	Protraction reaches	5	
	Standing straight arm across body pull	10	
Individual specific	Personal choice, preference or as prescribed		Use this section to complete any prescribed exercises or drills that you find beneficial prior to shooting

...Progress on to band and bow drills

Appendix 2 – SPSS Output

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
leftlathumep100	.086	48	.200*	.978	48	.499
leftlathumep200	.101	48	.200*	.985	48	.793
leftlathumep300	.117	48	.098	.965	48	.167

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
leftacrpro100	.097	48	.200*	.969	48	.241
leftacrpro200	.098	48	.200*	.974	48	.359
leftacrpro300	.080	48	.200*	.953	48	.051

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
leftradstypro100	.091	48	.200*	.977	48	.473
leftradstypro200	.123	48	.067	.960	48	.098
leftradstypro300	.118	48	.090	.974	48	.350

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
rightmedhumep100	.078	48	.200*	.975	48	.386
rightmedhumep200	.073	48	.200*	.969	48	.223
rightmedhumep300	.088	48	.200*	.971	48	.273

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
rightacrpro100	.099	48	.200*	.964	48	.151
rightacrpro200	.067	48	.200*	.973	48	.337
rightacrpro300	.097	48	.200*	.969	48	.235

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
rightradstypro100	.082	48	.200*	.970	48	.256
rightradstypro200	.090	48	.200*	.957	48	.076
rightradstypro300	.117	48	.102	.954	48	.057

RM ANOVA Output

LLHE

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
holdtime	.960	1.865	2	.393	.962	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	4.015	2	2.007	3.959	.022	.078
	Greenhouse-Geisser	4.015	1.924	2.087	3.959	.024	.078
	Huynh-Feldt	4.015	2.000	2.007	3.959	.022	.078
	Lower-bound	4.015	1.000	4.015	3.959	.052	.078
Error(holdtime)	Sphericity Assumed	47.657	94	.507			
	Greenhouse-Geisser	47.657	90.407	.527			
	Huynh-Feldt	47.657	94.000	.507			
	Lower-bound	47.657	47.000	1.014			

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-.209	.144	.462	-.568	.149
	3	-.409*	.158	.038	-.801	-.017
2	1	.209	.144	.462	-.149	.568
	3	-.200	.133	.417	-.529	.130
3	1	.409*	.158	.038	.017	.801
	2	.200	.133	.417	-.130	.529

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

LAP

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
holdtime	.985	.672	2	.714	.986	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	9.366	2	4.683	14.383	.000	.234
	Greenhouse-Geisser	9.366	1.971	4.751	14.383	.000	.234
	Huynh-Feldt	9.366	2.000	4.683	14.383	.000	.234
	Lower-bound	9.366	1.000	9.366	14.383	.000	.234
Error(holdtime)	Sphericity Assumed	30.608	94	.326			
	Greenhouse-Geisser	30.608	92.656	.330			
	Huynh-Feldt	30.608	94.000	.326			
	Lower-bound	30.608	47.000	.651			

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.428*	.110	.001	-.700	-.156
	3	-.608*	.122	.000	-.910	-.306
2	1	.428*	.110	.001	.156	.700
	3	-.180	.118	.400	-.473	.113
3	1	.608*	.122	.000	.306	.910
	2	.180	.118	.400	-.113	.473

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

LRSP

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
holdtime	.991	.416	2	.812	.991	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	10.749	2	5.375	10.977	.000	.189
	Greenhouse-Geisser	10.749	1.982	5.423	10.977	.000	.189
	Huynh-Feldt	10.749	2.000	5.375	10.977	.000	.189
	Lower-bound	10.749	1.000	10.749	10.977	.002	.189
Error(holdtime)	Sphericity Assumed	46.025	94	.490			
	Greenhouse-Geisser	46.025	93.161	.494			
	Huynh-Feldt	46.025	94.000	.490			
	Lower-bound	46.025	47.000	.979			

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.376*	.143	.035	-.731	-.020
	3	-.667*	.137	.000	-1.007	-.328
2	1	.376*	.143	.035	.020	.731
	3	-.292	.148	.165	-.660	.076
3	1	.667*	.137	.000	.328	1.007
	2	.292	.148	.165	-.076	.660

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

RMHE

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Epsilon[b] Lower-bound
holdtime	.950	2.350	2	.309	.953	.992	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	12.236	2	6.118	7.353	.001	.135
	Greenhouse-Geisser	12.236	1.905	6.423	7.353	.001	.135
	Huynh-Feldt	12.236	1.984	6.169	7.353	.001	.135
	Lower-bound	12.236	1.000	12.236	7.353	.009	.135
Error(holdtime)	Sphericity Assumed	78.211	94	.832			
	Greenhouse-Geisser	78.211	89.541	.873			
	Huynh-Feldt	78.211	93.225	.839			
	Lower-bound	78.211	47.000	1.664			

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	95% Confidence Interval for Difference[b] Upper Bound
1	2	-.172	.199	1.000	-.666	.321
	3	-.686*	.193	.003	-1.167	-.206
2	1	.172	.199	1.000	-.321	.666
	3	-.514*	.164	.009	-.922	-.106
3	1	.686*	.193	.003	.206	1.167
	2	.514*	.164	.009	.106	.922

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

RAP

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
holdtime	.997	.150	2	.928	.997	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	3.914	2	1.957	2.848	.063	.057
	Greenhouse-Geisser	3.914	1.994	1.964	2.848	.063	.057
	Huynh-Feldt	3.914	2.000	1.957	2.848	.063	.057
	Lower-bound	3.914	1.000	3.914	2.848	.098	.057
Error(holdtime)	Sphericity Assumed	64.610	94	.687			
	Greenhouse-Geisser	64.610	93.695	.690			
	Huynh-Feldt	64.610	94.000	.687			
	Lower-bound	64.610	47.000	1.375			

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-.403	.167	.060	-.818	.013
	3	-.175	.174	.959	-.607	.257
2	1	.403	.167	.060	-.013	.818
	3	.228	.166	.532	-.185	.640
3	1	.175	.174	.959	-.257	.607
	2	-.228	.166	.532	-.640	.185

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

RRSP

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Epsilon[b] Lower-bound
holdtime	.848	7.593	2	.022	.868	.898	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: holdtime

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
holdtime	Sphericity Assumed	28.959	2	14.479	18.740	.000	.285
	Greenhouse-Geisser	28.959	1.736	16.683	18.740	.000	.285
	Huynh-Feldt	28.959	1.797	16.119	18.740	.000	.285
	Lower-bound	28.959	1.000	28.959	18.740	.000	.285
Error(holdtime)	Sphericity Assumed	72.626	94	.773			
	Greenhouse-Geisser	72.626	81.585	.890			
	Huynh-Feldt	72.626	84.440	.860			
	Lower-bound	72.626	47.000	1.545			

Double-click to activate

Pairwise Comparisons

Measure: MEASURE_1

(I) holdtime	(J) holdtime	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	95% Confidence Interval for Difference[b] Upper Bound
1	2	-.642*	.146	.000	-1.004	-.280
	3	-1.093*	.207	.000	-1.608	-.578
2	1	.642*	.146	.000	.280	1.004
	3	-.451*	.180	.047	-.897	-.005
3	1	1.093*	.207	.000	.578	1.608
	2	.451*	.180	.047	.005	.897

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

Friedmans test output with Wilcoxon signed-rank

Friedman Test

Ranks

	Mean Rank
score100	2.25
score200	2.02
score300	1.73

Test Statistics[a]

N	48
Chi-Square	7.801
df	2
Asymp. Sig.	.020

a. Friedman Test

Test Statistics[a]

	leftradstypro 100 - leftradstypro 300	leftradstypro 100 - leftradstypro 200	leftradstypro 200 - leftradstypro 300
Z	-4.149[b]	-2.477[b]	-1.688[b]
Asymp. Sig. (2-tailed)	.000	.013	.091

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Appendix 3 – Measurement Protocol

Measurement Protocol

Equipment
Quintic Biomechanics Software v26
Gig-E Quintic Camera
Laptop
Ethernet Cable
Double-sided Tape
Marker Pen
Light Reflective Markers (4mm)
Scissors
Tape Measure
Scope
Stop Clock

Pre-Setup Precautions
1. Markers should be attached to double-sided tape the before measurement and cut out to save time on the day of testing.
2. Cameras should be connected and tested prior to testing to check functionality.
3. Parameters to track markers at 150fps will be pre-set and loaded to a 'Cam File' prior to testing.

System Setup
1. Only the lead researcher will be involved in any setup, calibration, testing and measurement procedures.
2. Connect Ethernet cable to camera and computer.
3. Open Quintic Biomechanics v26.
4. Click 'Single-high speed capture'.
5. Previously saved camera parameters will automatically load to record at 150fps.
6. Record object of known length and width for and name calibration.
7. Attach light reflective markers to desired anatomical landmarks, peeling off the reverse side of the double-sided tape (cross the skin with a marker to make replacing markers more accurate).

Measurement Procedure
1. The subject will shoot six arrows to sight in at a 70m target and place them suitability in the centre of the camera capture area.
2. Use the cue of the archer reloading the bow as the start of the video capture.
3. Suitably name each file dependent on hold time and arrow number (i.e. 100% 70m arrow 1).
4. Click 'Record' and stop each recording after the release of the arrow.
5. Use scope to record the score of the arrow.
6. Repeat for each arrow shot.

7. For extended hold times count aloud in reverse to notify the participant when to release the arrow.

Data Processing Procedure

1. Load calibration file and enter dimensions.
2. Load video file from appropriate folder.
3. Create frame template and name each marker.
4. Select frame template.
5. Click ‘automatic digitisation’.
6. Crop video file to one second prior to execution and a third of a second after (200 frames).
7. Click on each marker with the suitable label.
8. Click ‘Start Tracking’.
9. Select Butterworth Low-Pass Filter.
10. Click ‘Linear Analysis’
11. Save Results (Microsoft Excel 2013 files will be created).

(Appendix 4)

University of Chester

Faculty of Life Sciences
Research Ethics Committee

frec@chester.ac.uk

26/06/2015

Lewis Marsden
The Spinney
Burnley

Dear Lewis

Study title: Stability of Alignment During Extended Hold Times in the Aiming Phase of Elite Recurve Archers
FREC reference: **1077/15/LM/SES**
Version number: **1**

Thank you for sending your application to the Faculty of Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	May 2015
Appendix 1 – List of References	1	May 2015
Appendix 2 – Summary CV for Lead Researcher	1	May 2015
Appendix 3 – Letter(s) of invitation to participants	2	June 2015
Appendix 4 – Participant Information Sheet [PIS]	2	June 2015
Appendix 5 – Participant Consent Form	1	June 2015
Appendix 6 – Written permission(s) from relevant personnel	1	May 2015
Appendix 7 – Risk Assessment	1	May 2015
Appendix 8 – Summary CV of other individual working on research project.	1	May 2015
Response to FREC request for further information or clarification.		May 2015

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Dr. Stephen Fallows
Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative

Pre-test Questionnaire (Appendix 5)

Stability of Alignment During Extended Hold Times in the Aiming Phase of Elite Recurve Archers

Researcher : Lewis Marsden

Name:___________________________________ Test date:_________________

Contact number:______________________________ Date of birth:____________

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor?	YES/NO
2. Do you feel pain in the chest when you perform physical activity?	YES/NO
3. In the past month, have you had chest pain when you were not performing physical activity?	YES/NO
4. Do you lose your balance because of dizziness *or* do you ever lose consciousness?	YES/NO
5. Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity?	YES/NO
6. Is your doctor currently prescribing drugs for your blood pressure or heart condition?	YES/NO
7. Are you pregnant, or have you been pregnant in the last six months?	YES/NO
8. Have you injured your hip, knee or ankle joint in the last six months?	YES/NO
9. Do you know of any other reason why you should not participate in physical activity?	YES/NO

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

(Appendix 6)

Stability of Alignment During Extended Hold Times in the Aiming Phase of Elite Recurve Archers

Dear Participant,

My name is Lewis Marsden. I am a post-graduate student in the Sport and Exercise Science Department at the University of Chester. I am conducting a research study as part of the requirements of my Masters degree in Sports Biomechanics, and I would like to invite you to participate.

I am studying the role of isometric training on stability in archery. If you decide to participate, you will be asked to take part in a protocol that will test the stability of alignment during extended hold times in the aiming phase. Stability will be tested on 18 arrows with varying hold-times. The testing will take place at Lilleshall National Sports Centre, July 2015.

You may feel uncomfortable extending hold times. You do not have to continue participation if you do not wish to. You may benefit from the study by improving your stability in overhead alignment in

Participation is confidential. Study information will be kept in a secure location at the University of Chester. The results of the study may be published or presented at professional meetings, but your identity will not be revealed.

Taking part in the study is your decision. You do not have to be in this study if you do not want to. You may also quit being in the study at any time.

We will be happy to answer any questions you have about the study. You may contact me at (1428945@chester.ac.uk) or my research supervisor, (Dr Grace Smith, g.smith@chester.ac.uk) if you have study related questions or problems.

Thank you for your consideration. If you would like to participate please contact me either by telephone or email.

With kind regards,

Lewis Marsden.

(Appendix 7) Participant information sheet
Stability of Alignment During Extended Hold Times in the Aiming Phase

of Elite Recurve Archers.

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
This research is being undertaken in elite archers. The project is to find out whether isometric training improves stability in overhead alignment in archery.

This has been chosen to facilitate extended hold times elicited during competition that surpass functional training demands in an attempt to increase isometric capacity.

Why have I been chosen?
You have been chosen to take part in this study because you are an elite recurve archer.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will complete an archery specific warm-up before shooting 6 arrows at a 10m blank boss. Following this you will shoot 6 arrows at 70m-target face, followed by 6 at 200% of your functional hold time and 6 at 300%.

What are the possible disadvantages and risks of taking part?
Possible disadvantages may include mild muscle soreness or the delayed onset of muscle soreness through an increase in muscular demand in comparison to normal demands on programme.

What are the possible benefits of taking part?
Serves to highlight improved strategies when faced with extended hold times.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact the **Dean** of the Faculty of Life Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?
The research is conducted as part of an MSc in Sports Biomechanics within the Department of Sport and Exercise Science at the University of Chester. The study is organised with supervision from the department, by Lewis Marsden, an MSc student.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Lewis Marsden. 1428945@chester.ac.uk.

Thank you for your interest in this research.

(Appendix 8) Stability of Alignment During Extended Hold Times in the Aiming Phase of Elite Recurve Archers.

Name of Researcher: Lewis Marsden

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

3. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Researcher	Date	Signature

.